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PATENT SPECIFICATION

DRAWINGS ATTACHED

930,474

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COMPLETE SPECIFICATION

Improvements in Centrifugal Pumps and the like

We, RESEARCH AND DEVELOPMENT PTY. LTD., a Corporation of the State of Western Australia, of 50, Miller Street, North Sydney, New South Wales, Australia, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to centrifugal pumps, blowers, fans, compressors and like centrifugal units of the volute type which will hereinafter be referred to as centrifugal pumps for convenience.

One object of the invention is to provide more efficient pump components and constructions. Another object is to provide a pump casing which, when the pump is used for pumping abrasive material, is less liable to wear. A further object is to provide casing components which are readily and separately renewable and which may be made of materials of differing physical properties. Other objects are to provide improved components and constructions as hereinafter described.

In any centrifugal pump, whatever its type or construction, the fluid discharged from the impeller into the casing has a variable total energy—variable both as to time and point of discharge from the impeller. In the casing there are losses of fluid energy. These losses are not uniform throughout the fluid and tend further to distort the already uneven distribution of energy of the fluid leaving the impeller. Losses of fluid energy in the casing occur chiefly at the cutwater, adjacent the containing surfaces and in the discharge branch.

In conventional pumps the fluid of higher energy issues from the impeller within a disc-like layer substantially normal to the axis of rotation and of less thickness than the axial width of the impeller passages. If the impeller has a single axial intake from one side the disc layer will be towards or against the opposite side wall of the impeller passages. If the impeller is symmetrical in axial section and has axial fluid entry from both sides and flow rates from each side are substantially equal the disc layer will emerge more or less centrally from the periphery of the impeller.

It is a fundamental physical requirement of fluid flow in a curved path that the fluid of higher total energy will move to and displace lower energy fluid from the outer portion of the path. The higher energy fluid within the disc-like layer emerging from the impeller consequently moves to the outer portion of the casing where it circulates until either it passes into the discharge branch of the casing or, by shock and turbulence from the cutwater or friction against the casing surfaces, it loses energy sufficient to be displaced toward the axis of the pump by fluid of higher energy. The displaced fluid constitutes a return flow moving towards the impeller and, superimposed on the main flow, gives rise to spiral flows in the casing. If the disc layer of higher energy fluid emerges from the impeller symmetrically with respect to the casing the flow in the casing consists of right and left hand spiral flows of approximately equal strength moving outwards in the centre of the casing and inwards adjacent each of the sidewalls towards the axis of the pump. The result of the fluid movements described is that fluid of lower energy is displaced to positions adjacent the peripheries of the running clearances between the impeller and the sidewalls of the casing and portion of it passes into the clearances from where it either returns to the casing by being re-energised by the side disc friction of the rotating impeller or joins the fluid entering the intake opening of the impeller. If the disc layer of higher energy fluid

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emerges from the impeller asymmetrically with respect to the casing then the spiral flows will correspondingly differ in size and strength and more or less lower energy fluid will be displaced to each side of the impeller. When the fluid contains solids in suspension the solids, particularly if large and of high density relative to the fluid in which they are transported, lose even more energy than does the fluid by shock and turbulence from the cutwater and friction aaginst the casing surfaces and tend to become concentrated in the lower energy fluid and to pass with it into the running clearances between the impeller and the casing and there cause rapid wear of the parts and consequent reduced performance of the pump. Certain features of this invention provide zones of higher energy fluid adjacent the peripheries of the running clearances between the impeller and the sidewalls of the casing which act as barriers to isolate these clearances from the lower energy fluid in the casing.

In conventional pumps the discharge branch forms on the one side a continuation of the casing at its maximum radius and hence it preferentially discharges the higher energy fluid which occupies the outer portion of the casing. The other or cutwater side of the discharge branch is adjacent the periphery of the impeller and extends for the full width of the casing at this point. Consequently the higher energy fluid issuing from the impeller impinges directly on the cutwater and even under the most favourable conditions at best efficiency point considerable shock and turbulence take place with corresponding loss in efficiency. When the fluid contains solids in suspension, as with slurry or dredge pumps, the shock and turbulence from impingement on the cutwater and resultant production of lower energy fluid with a higher than average concentration of solids is most potent cause of wear of the pump components. This invention so provides that the cutwater can be of substantially less width than the casing It also provides that the cutwater may be so positioned that it cuts only fluid of lower energy. In these ways efficiency can be improved and wear reduced.

In conventional pumps a portion of the disc layer of higher energy fluid issuing from the impeller enters the discharge branch directly without impinging on any surface and, having moved the least distance of any fluid in the casing, has the highest energy of all fluid entering the discharge branch. It is flanked on either side in an axial direction by fluid of lower energy entering the discharge branch and this lower energy fluid is held towards the cutwater side by higher energy fluid occupying the outer portion of the discharge branch. Conventionally the discharge branch comprises a diverging nozzle with a substantially straight axis and its object is to convert fluid kinetic energy into pressure at the discharge flange. As the axis is straight the pressure over any cross section of the discharge branch is substantially uniform so that variation in energy level of the fluid entering the branch from the casing appears as variation in kinetic energy and hence as variation in velocity over the cross section, areas of higher velocity corresponding with the areas occupied by fluid of higher energy. It is well known that it is not possible efficiently to convent fluid kinetic energy to pressure in a diverging nozzle when the velocity distribution is sensibly non-uniform and as the conversion corresponds to that to be expected from the lower velocity fluid, substantial loss of energy is sustained by the fluid of higher velocity. Features of this invention enable the fluid to enter the discharge branch with substantially uniform energy and velocity and thereby allow a higher efficiency of conversion of kinetic energy to pressure to be attained than is possible in a conventional pump.

Generally in a centrifugal pump of the volute type and of the type referred to, according to the invention, means are provided for segregating and directing or for producing, segregating and directing fluid of differing energy levels so that in the casing fluid of higher energy level envelops or substantially envelops fluid of lower energy level.

As a means of preserving the envelope of higher energy fluid and also of ensuring the greatest uniformity in the level of the energy of the fluid leaving the casing the entry to the discharge branch from the casing is so located and shaped as to receive preferentially fluid of lower energy level and to exclude fluid of high energy level. As a result fluid energy losses resulting from casing wall contact are borne substantially by the higher energy fluid.

In one specific form the invention comprises an impeller so shaped that its discharge consists of two peripheral side zones of higher energy fluid separated by a zone of lower energy fluid, the zones of higher energy being directed towards the casing sidewalls adjacent the periphery of the impeller. The shape of the impeller controls the difference in energy levels of the fluid discharged by the impeller so that the energy level of the higher energy fluid is reduced in the casing to substantially that of the lower energy fluid at entry to the discharge branch of the casing.

Some specific forms of the invention are illustrated in the accompanying drawings, wherein:—

Figs. 1, 2 and 3 are axial sections showing variant forms of impeller and casing.

Fig. 4 is a section on line AA of Fig. 1 with supporting shell members removed.

Fig. 5*a* is a fragmentary section of the casing on line BB of Fig. 4.

Fig. 5*b* is a fragmentary section of the casing on line CC of Fig. 4.

Fig. 5*c* is a fragmentary section of the casing on line DD of Fig. 4.

Fig. 5*d* is a fragmentary section of the casing on line EE of Fig. 4.

Fig. 5*e* is a fragmentary section of the casing on line FF of Fig. 4.

Fig. 5*f* is a fragmentary section of the casing on line GG of Fig. 4.

Fig. 6*a* is an elevation of the discharge branch of the casing viewed in the direction of the arrows HH of Fig. 4.

Fig. 6*b* is a fragmentary section of the casing on line JJ of Fig. 4.

Fig. 6*c* is a fragmentary section of the casing on line KK of Fig. 4.

Fig. 6*d* is a fragmentary section of the casing on line LL of Fig. 4.

Like parts are illustrated by like characters throughout the specification and drawings.

As shown in the drawings an impeller 1 is mounted on a shaft 2 for anticlockwise rotation (as viewed in Fig. 4) within a casing assembly 3. Impeller vanes 4 connecting impeller back plate 5 and front plate 6 form passages 7 leading from axial inlet 8 to outlets 9. The impeller plates may be provided with auxiliary side vanes 10 as shown in Figs. 1 and 2. In an open form of the impeller illustrated in the lower half of Fig. 1 the front plate 6 with its front auxiliary vanes 10 is omitted and the main vanes 4 extend axially to conform with suitable side running clearance to the surface of the adjacent casing side member.

One means of controlling the impeller discharge in accordance with the invention, illustrated in the upper half of Fig. 1 and in Figs. 2 and 3, comprises a peripheral groove 11 in the vanes 4 the effect of which is to reduce the energy imparted by the impeller to the fluid issuing from the impeller passages in the region of the groove so that the discharge from the impeller consists of two peripheral side zones 12 of higher energy fluid separated by a zone 13 of lower energy fluid. As illustrated the groove 11 is offset from the centreline of the impeller vane towards the back plate 5 with the objective of counteracting the effect of the single axial intake which would otherwise cause the fluid to issue from the impeller with energy and volume greater adjacent the back plate 5 than adjacent the front plate 6. The extent, shape and position of the profiled portion of the vanes depends on the relative energy levels, volumes, positions and flow directions of the fluid energy zones required by a particular pump construction and the point of operation on the pump characteristic performance curve. Thus as illustrated at 14 in the lower half of Fig. 1 the groove may extend to the back plate of the impeller which may extend beyond the vane diameter adjacent to it, as at 15, to produce by frictional drag on the fluid a restricted zone of higher energy fluid. Such an impeller construction producing a restricted zone of higher energy fluid may also be used for instance where the casing discharge branch is required for constructional reasons to be offset from the centre line of the impeller. Another means of controlling the impeller discharge is by curving in a convex manner outwardly towards the periphery of the impeller, as at 16, the impeller side plate surface or surfaces to which the vanes 4 join so as to assist in directing towards, and delivering adjacent the side wall or walls, the higher energy fluid 12.

In the open form of impeller shown in the lower half of Fig. 1 the peripheral diameter of the vanes 4 is largest at 17 adjacent the side wall of the casing and has the effect not only of imparting more energy to the fluid leaving the impeller in this region but also of bestowing on the fluid flow an axial component towards the adjacent side wall of the casing.

Any of the means described for controlling the impeller discharge may be used in combination to produce the required results.

The higher energy fluid 12 directed by the impeller towards the casing walls adjacent its periphery moves outwards along the walls to occupy the outer portion of the casing and passes, as its energy level is reduced by friction with the walls, into the centre of the casing to join the lower energy fluid 13 discharged directly by the impeller. In this manner the higher energy fluid forms an envelope about the lower energy fluid, sustaining the losses from friction with the walls and isolating the low energy fluid from the impeller clearance spaces 18.

By locating the entry 19 (see Fig. 4) to the discharge branch 20 from the casing at a shorter distance from the pump axis than the outer wall 21 of the casing nearby, the higher energy fluid is excluded from the discharge. Typically the entry to the discharge branch is located in a raised portion of the casing projecting inwardly towards the axis of the pump. The raised portion takes the form of an elongated circumferential ridge 22 (see Fig. 5*c*) with sloping sides 23, the ends fading gradually into the casing wall as at 24 and 25 (see Fig. 4) and being shaped so as to minimise disturbance to the fluid flow in the casing. Sufficient area alongside the ridge 22 is provided to allow the higher energy fluid to by-pass the entry to the discharge branch. The ridge 22 is in general symmetrically positioned with respect to the casing as viewed in axial section but may be offset to suit some types of pump construction.

The entry 19 to the discharge branch is in the form of an elongated circumferential slot occupying substantially the whole of the width of the top of the ridge 22 which is substantially less than the width of the casing. One end of the slot forms the cutwater 26 the width of which is consequently also substantially less than the width of the casing. In effect the ridge 22 penetrates the envelope of higher energy fluid 12 and places the entry to the discharge branch in a position to receive preferentially the lower energy fluid 13. The loss of energy at the cutwater 26 is a minimum because the cutwater has the least possible width and cuts only the fluid of lower energy.

To ensure minimum loss of energy the area and attitude of the entry to the discharge branch are so arranged as to allow the fluid to pass from the casing into the discharge branch with velocity substantially unchanged in both direction and magnitude. The area of cross section of the discharge branch 20 provided at the cutwater Section L—L (Fig. *6d*) is such that the velocity of the fluid passing this cross section is substantially the same as at the entry 19 to the discharge branch. The portion of the discharge branch from the cutwater cross section L—L to the discharge flange 27 is of increasing cross sectional area and so shaped that the centres of area of cross sections (Figs. *6a* to *6d* inclusive), lie on a straight line substantially normal to the discharge flange, the rate of increase of cross sectional area being low enough throughout to ensure that high efficiency of conversion of the fluid kinetic energy to pressure at the discharge flange 27 is achieved. The shape of the discharge branch 20 is such that the walls are regular in the direction of fluid flow and transition in change of direction and of shape and area of cross section is gradual, as shown in Figs. 4 and *5a* and Figs. *6a* to *6d* inclusive.

Within the casing the cross sectional area increases uniformly from the cutwater 26 to the commencement of the discharge branch at 28 in the direction of rotation to accommodate fluid discharged by the impeller 1. From the commencement of the discharge branch at 28 to the cutwater 26 in the direction of rotation the cross sectional area of the casing decreases so as to maintain a constant average fluid velocity in this portion of the casing as fluid enters the discharge branch 20.

The casing comprises separately renewable sections shaped according to the invention with suitable joints between. For abrasive duty the casing sections are constructed of wear resistant materials and are supported and located by separate shell members. Such constructions are illustrated in Fig. 1 for a low specific speed type pump and in Fig. 2 for a pump of higher specific speed. For non-abrasive or very slightly abrasive duty the casing sections are self-supporting and self-locating. Such a construction is illustrated in Fig. 3. The upper halves of Figs. 1 and 2 illustrate abrasion resisting construction in resilient material such as natural or synthetic rubber reinforced where necessary with metal. The lower halves of these figures illustrate abrasion resisting constructions in hard metal.

A half outer casing section shaped according to the invention is shown in resilient material construction as 29 in Figs. 1 and 2. It carries half of the ridge 22 and half of the discharge branch 20 and has a flange 30 adapted to be jointed on the plane of symmetry of the casing to a half outer casing section 31 of opposite hand. The outer half casing sections each have a side flange 32 adapted to make a joint in the manner shown with the casing side section.

The intake side casing section 33 is a disc-like member formed of wear resistant material such as resilient natural or synthetic rubber bonded to a metal reinforcing plate 34 which carries a hollow cylindrical metal portion 35 to which is bonded the rubber lining 36 of the intake branch 37. The cylindrical metal reinforcement 35 is provided with an annular shoulder 38 against which bear tapered cotters 39 driven through slots in the supporting intake side shell member 40. Driving of the cotters 39 draws the intake side casing section 33 tightly against the resilient flange 32 of the outer casing section 29 which is supported by the shell member 40 and a fluid-tight joint is thus made with the resilient facing 41 of the side casing section. The rubber-lined intake branch 37 of the side casing section 33 projects slightly beyond the face of the flange 42 of the shell member 40 and is adapted to make a fluid-tight joint with an intake pipe bolted to the flange. The intake side casing section 33 may be bevelled as at 43 in Fig. 2 to conform with the direction and facilitate the movement of the higher energy fluid flow from the impeller. A conical projection 44 to which the impeller conforms, is provided about the intake branch 37 to facilitate the entry of abrasive slurry into the impeller and direct abrasive particles away from the side clearance space 18 between the impeller and the casing side section.

The shaft side casing section 45 is a disc-like member formed of resilient material such as natural or synthetic rubber bonded to a metal reinforcing plate 46. It has an annular projection 47 to the outer surface of which the auxiliary vanes 10 on the impeller conform with suitable running clearance, the purpose of the projection being to return to the vanes fluid leakage from the running clearance between the impeller and the casing side section. The reinforcing

plate 46 is provided with threaded bosses 48 into which studs 49 are screwed. The studs pass through holes in the shell member 50 and are provided with nuts 51 which may be tightened to draw the casing section 45 against the flange 32 of the outer casing section 31 and against the face 52 of the seal member 53, where fluid-tight joints are thus made. The shaft side casing section 45 may be bevelled as at 54 in Fig. 2 to conform with the direction and facilitate the movement of the higher energy fluid flow from the impeller.

The shell members 40 and 50 which locate and support the casing sections are drawn together by suitable bolts not shown in the figures and press together the resilient flanges 30 of the outer casing sections to make a fluid-tight joint. The shell member 50 is adapted to locate and support interchangeably various forms of impeller shaft sealing means and to attach to a frame not shown in the figures for supporting the shaft bearings and maintaining alignment of the various parts.

An outer casing section shaped according to the invention is shown in one piece hard metal construction as 55 in the lower half of Fig. 1. It has raised annular faces 56 which may be rough ground and are adapted to make fluid-tight joints with annular sealing rings 57 of resilient material supported by the shell members 40 and 50 respectively. In the lower half of Fig. 2 is shown a two piece hard metal construction of the outer casing section the half sections 58 and 59 being of opposite hand and having flanges 60 between which a fluid-tight joint is made by means of a gasket 61 of resilient material. The half outer casing sections are each provided with raised annular faces 56 which may be rough ground and are adapted to make fluid-tight joints with the annular sealing rings 57. The hard metal outer casing sections are shaped and sized externally so as to be everywhere clear of the shell members 40 and 50 from which they are supported, and have joint sealing pressure applied, through the joint rings 57.

The hard metal intake side casing sections 62 shown in the lower halves of Figs. 1 and 2 are similar in shape and size to the corresponding sections in rubber covered construction illustrated in the upper halves of the figures. The raised annular face 63, which may be rough ground, is pressed against the resilient ring 57 to make a fluid-tight joint by driving the tapered cotters 39 which pass through slots in the shell member 40 and bear on the annular shoulder 38.

The hard metal shaft side casing sections 64 are similar in most respects to the corresponding sections in rubber covered construction. The raised annular face 63 which may be rough ground, is pressed against the resilient ring 57 by tightening the nuts of bolts 65 which pass through the shell member 50 in the manner of the studs 49 and which engage by means of square heads 66 and locknuts 67 suitable lugs 68 cast integrally with the side casing section 64. Resilient gaskets 69 and 70 serve to make fluid-tight joints between the casing side section 64 and adjacent seal member 71.

The self supporting casing construction illustrated in Fig. 3 comprises two casing sections 72 and 73 face-jointed with a gasket at 74 and held together by studs 75 and nuts 76. Casing section 72 is flanged as at 77 for attaching to any suitable supporting frame and is provided with sealing means 78 where the shaft 2 supporting the impeller 1 passes through the casing. Casing section 72 has a cylindrical opening 79 co-axial with the impeller and of diameter sufficiently large to permit easy removal of the impeller when the casing section 73, which closely fits the opening, is removed. The axial dimensions of the casing sections are such that when assembled the faced annular projections 80 and 81 on the respective sections are a close running fit with corresponding faced annular projections 82 and 83 on the sides of the impeller. The casing section 73 is provided with the intake branch 84 which may be flanged as at 85 or otherwise adapted for connection to an intake pipe. Casing section 72 is provided with integral discharge flange 86 or other suitable means for connection to a discharge pipe.

As depicted in Fig. 3 the impeller and casing are for a pump of medium specific speed. Beyond the diameter of the impeller the walls of the casing diverge as at 87 and the outward flare of the impeller side plates and the dimensions and location of the groove 11 in the periphery of the impeller vanes are such as to project the streams 12 of higher energy fluid leaving the impeller adjacent and parallel to the diverging walls of the casing. The outer portion and discharge branch of the casing section 72 is shaped on its internal surface substantially as previously described with reference to Figs. 4, 5 and 6.

WHAT WE CLAIM IS:—

1. Means in a centrifugal pump of the volute type and of the type referred to for segregating and directing or for producing, segregating and directing fluid of differing energy levels so that in the casing fluid of higher energy level envelops or substantially envelops fluid of lower energy level.

2. Means according to Claim 1 comprising a pump casing with the entry to its discharge branch so located and shaped as to receive preferentially fluid of lower energy level.

3. Means according to Claim 1 characterized in that fluid energy losses resulting from

casing wall contact are borne substantially by the higher energy fluid.

4. Means according to Claim 1 comprising an impeller so shaped that its discharge consists of two peripheral side zones of higher energy fluid separated by a zone of lower energy fluid, the zones of higher energy being directed towards the casing sidewalls adjacent the periphery of the impeller, further characterised in that the difference in energy levels of the fluid discharged from the impeller is so controlled by the shape of the impeller that the energy level of the higher energy fluid is reduced by losses in the casing to substantially that of the lower energy fluid at entry to the discharge branch of the casing.

5. Means according to Claim 4, characterised in that the periphery of the impeller vanes is profiled as viewed in axial section, the extent, shape and position of the portions of various diameter depending on the relative energy levels, volumes, positions and flow directions of the fluid energy zones required by a particular pump construction and the point of operation on the pump characteristic performance curve.

6. Means according to Claim 5 characterised in that the impeller vanes are grooved at their peripheries substantially as described in the body of the specification and with reference to the drawings.

7. Means according to any one of Claims 4 to 6 inclusive characterised in that the higher energy fluid is produced either wholly or partly by an impeller side plate extension beyond the vane diameter adjacent thereto.

8. Means according to any one of Claims 4 to 6 inclusive characterised in that when the vanes at their peripheries extend to adjacent a sidewall of the casing their outside diameter is there increased to produce and direct towards the sidewall the higher energy fluid.

9. Means according to any one of Claims 4 to 8 inclusive characterised in that the side-plate surface, or either or each if there are two such surfaces, to which the vanes join is curved convex outwards towards the periphery of the impeller and assists to direct towards and deliver adjacent to a sidewall of the casing the higher energy fluid.

10. Means according to any one of Claims 4 to 9 inclusive constructed so that in operation the higher energy fluid forms a barrier between the impeller side clearance space and the fluid of lower energy in the casing.

11. Means according to any one of the preceding claims constructed so that in operation the higher energy fluid discharged from the impeller moves outwards adjacent a sidewall of the casing.

12. Means according to Claim 2, characterised in that the preferential fluid reception is achieved by locating the entry to the discharge branch from the casing at a less distance from the pump axis than the casing outer wall nearby.

13. Means according to Claim 12 characterised in that the entry to the discharge branch from the casing is located in a raised portion thereof projecting inwardly towards the axis of the pump.

14. Means according to Claim 13 characterised in that the raised portion has the form of an elongated circumferential ridge the ends of which fade gradually into the casing wall and are so shaped as least to disturb the fluid flow in the casing.

15. Means according to Claim 14 characterised in that the cross sectional area of the casing alongside the ridge is sufficient to allow the higher energy fluid to by-pass the entry to the discharge branch.

16. Means according to any one of Claims 13, 14 and 15, characterised in that with respect to the casing the raised portion or ridge is symmetrically positioned as viewed in axial section.

17. Means according to any one of Claims 12 to 16 inclusive characterised in that the entry to the discharge branch from the casing is an elongated circumferential slot of substantially less width than the casing.

18. Means according to any one of Claims 12 to 17 inclusive characterised in that the area and attitude of the entry to the discharge branch is such as to allow the fluid to pass from the casing into the discharge branch with velocity substantially unchanged in both direction and magnitude.

19. Means according to any one of Claims 12 to 18 inclusive characterised in that the width of the cutwater is substantially less than the width of the casing.

20. Means according to any one of Claims 12 to 19 inclusive characterised in that the cutwater is so positioned that it cuts only fluid of lower energy.

21. Means according to any one of Claims 12 to 20 inclusive characterised in that the area of cross section of the discharge branch at the cutwater is such that the fluid velocity at this cross section is substantially the same as at the entry to the discharge branch.

22. Means according to any one of Claims 12 to 21 inclusive characterised in that the portion of the discharge branch from the cutwater to the discharge flange is of increasing cross sectional area and so shaped that the centres of area of cross section lie on a substantially straight line normal to the discharge flange, the rate of increase of cross sectional area being low enough throughout that high efficiency of conversion of the fluid kinetic energy to pressure at the discharge flange is achieved.

23. Means according to any one of Claims 12 to 22 inclusive characterised in that the shape of the discharge branch is such that

the walls are regular in the direction of fluid flow and transition in change of direction and of shape and area of cross section is gradual.

24. Means according to any one of Claims 12 to 23 inclusive characterised in that the casing increase uniformly in cross sectional area from the cutwater to the commencement of the discharge branch in the direction of rotation to accommodate fluid discharge by the impeller.

25. Means according to any one of Claims 12 to 24 inclusive characterised in that the casing decreases in cross sectional area from the commencement of the discharge branch to the cutwater in the direction of rotation so as to maintain a constant average fluid velocity in this portion of the casing.

26. Means according to any of Claims 12 to 25 inclusive characterised in that the casing comprises separate sections with suitable joints between, the sections being supported and located by any suitable means.

27. A means according to Claim 26 including any one of the separate casing sections substantially as described in the body of the specification with reference to the drawings.

28. Improvements in centrifugal pumps substantially as described in the body of the specification with reference to the drawings.

29. For a centrifugal pump, an impeller as defined in any one of Claims 4, 5, 6, 7, 8, 9, 10 or 11.

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930474 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

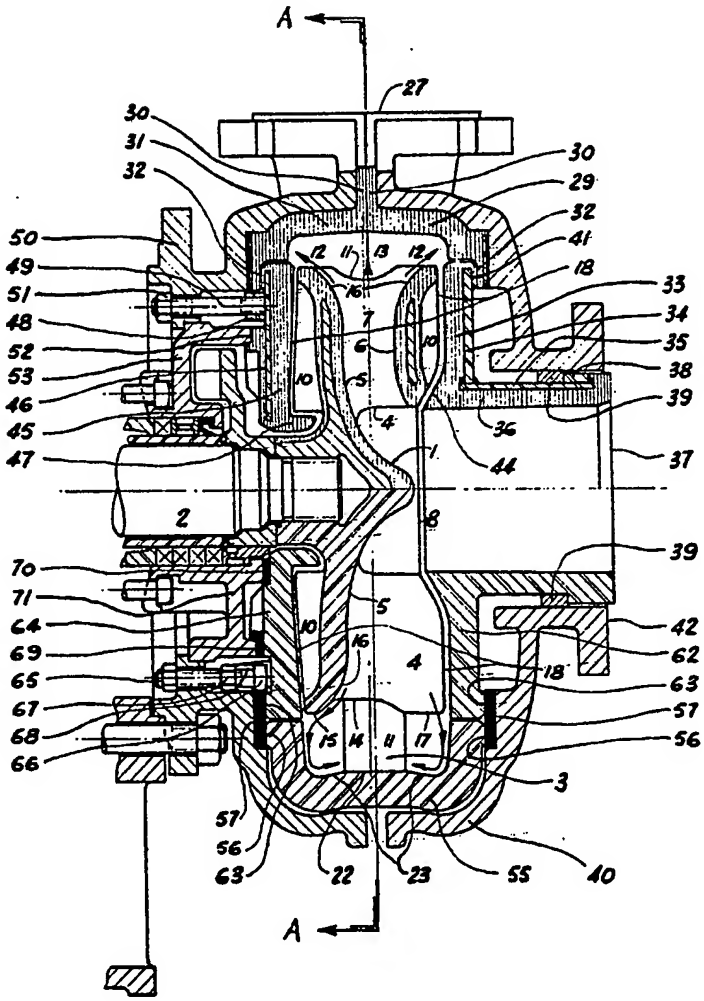

Fig.1

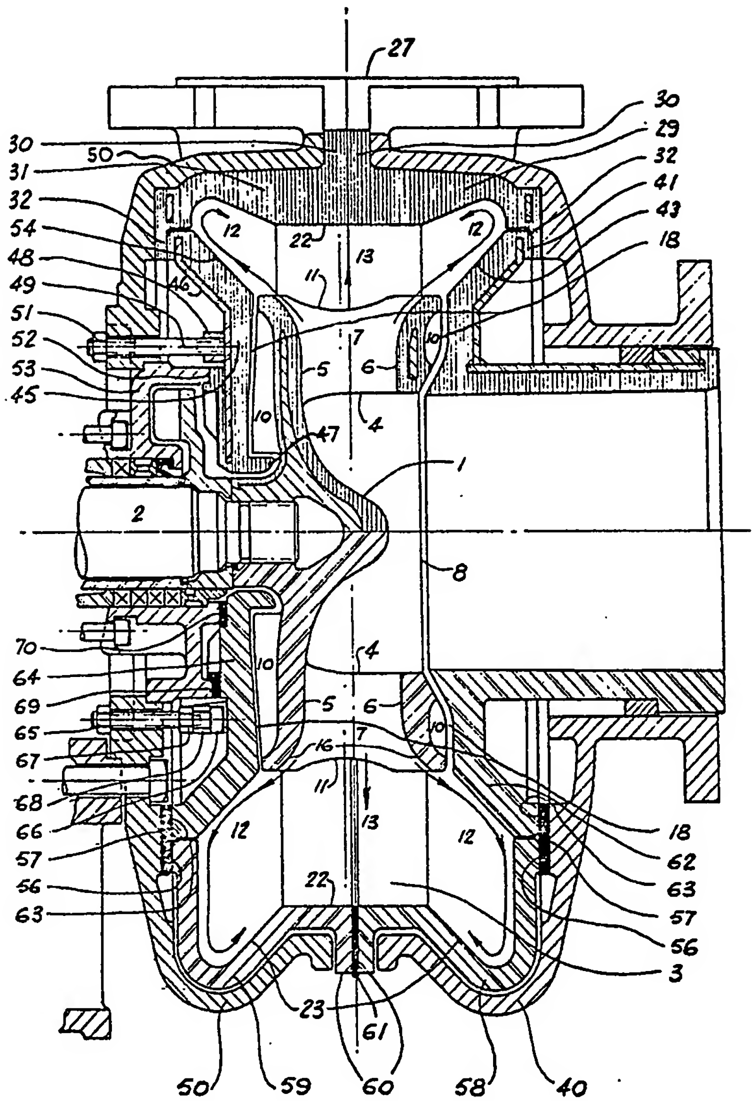
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Fig. 2

930474 COMPLETE SPECIFICATION

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Sheets 2 & 3

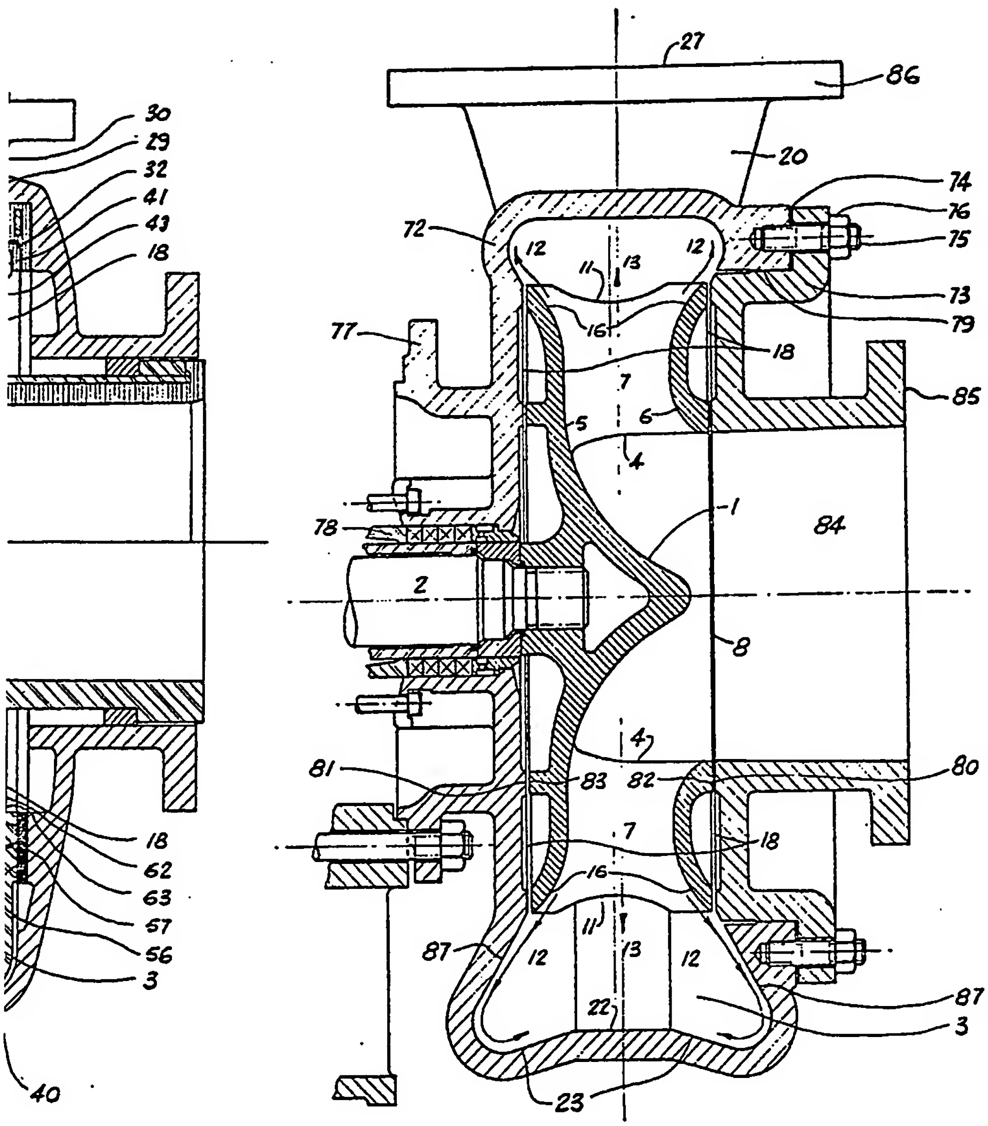

Fig. 3

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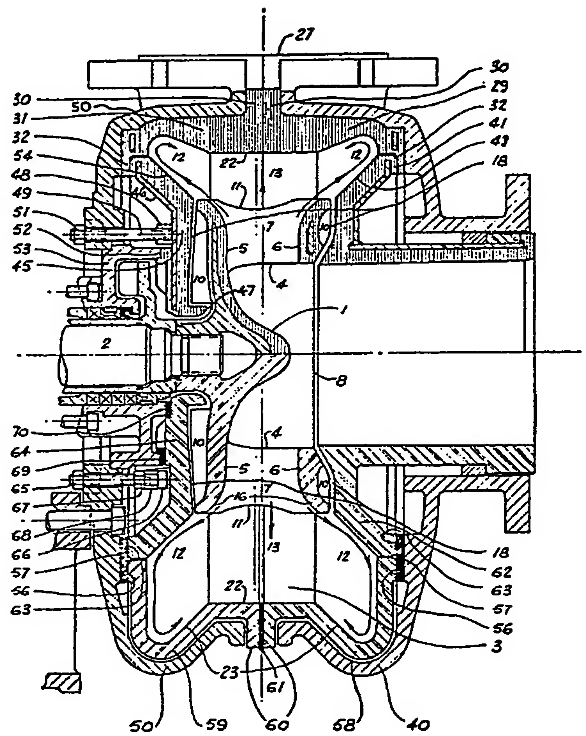

Fig. 2

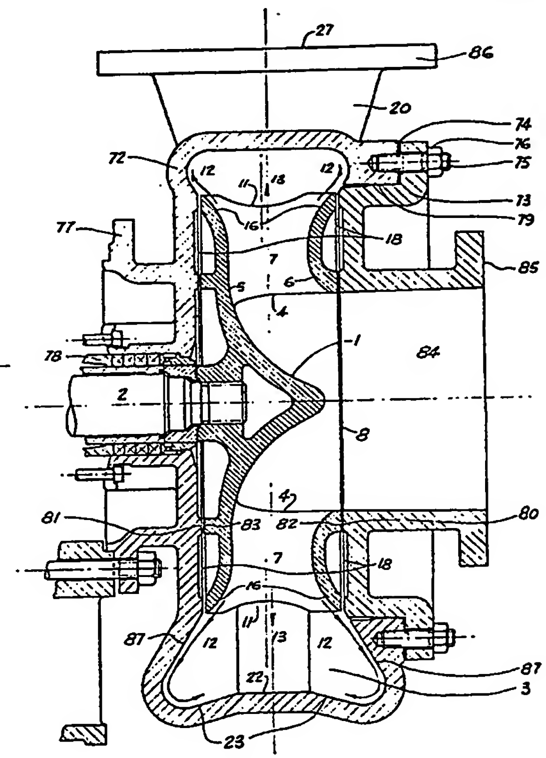

Fig. 3

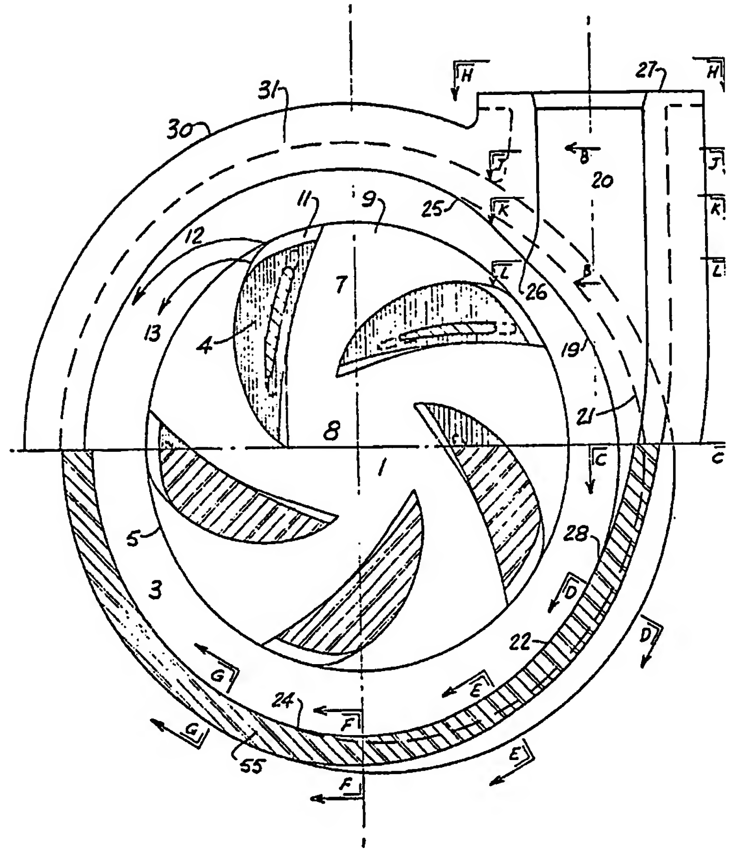

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Fig. 4

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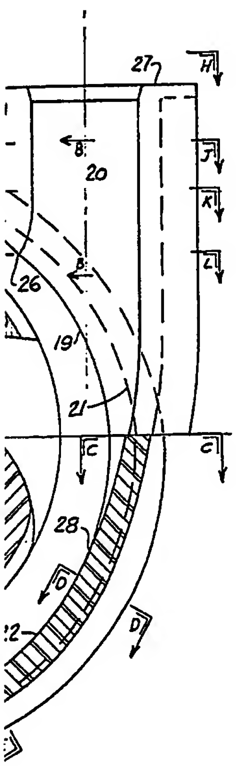
Sheets 4 & 5



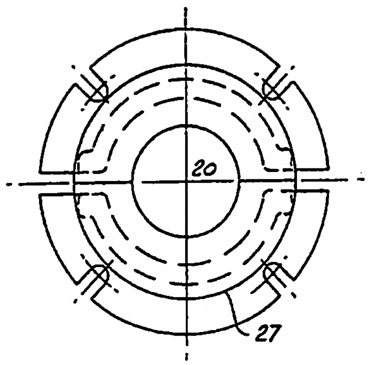


Fig. 6a

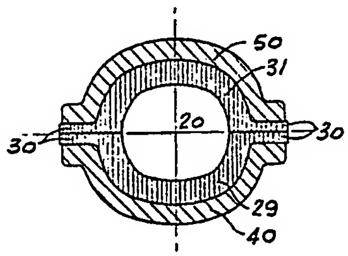


Fig. 6b

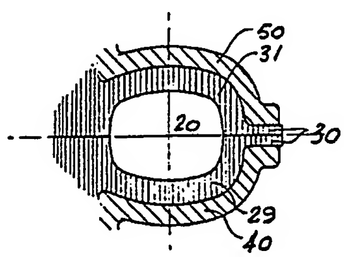


Fig. 6c

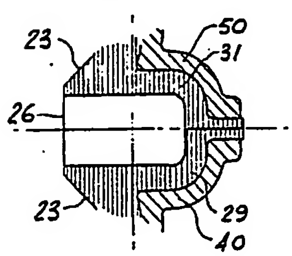


Fig. 6d

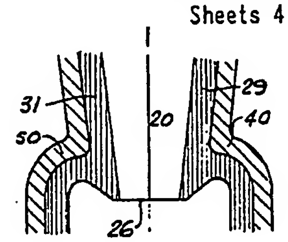


Fig. 5a

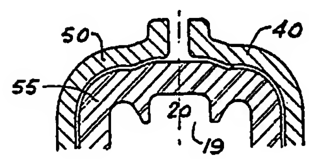


Fig. 5b

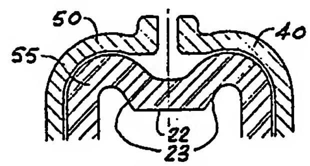


Fig. 5c

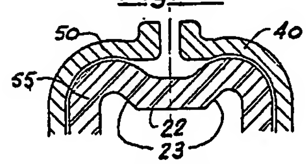


Fig. 5d

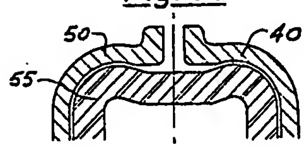


Fig. 5e

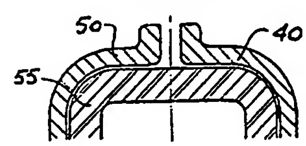


Fig. 5f

930474 COMPLETE SPECIFICATION
5 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 4 & 5

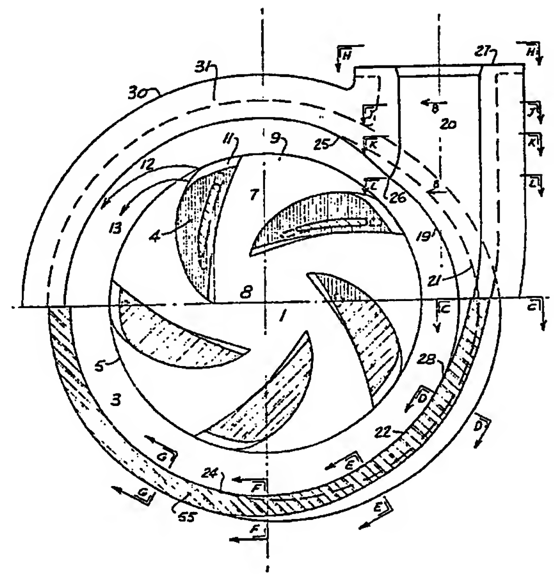


Fig. 4

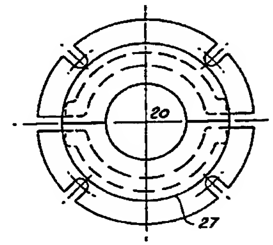


Fig. 6a

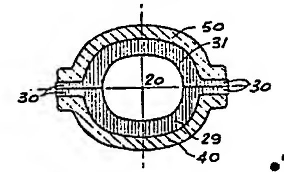


Fig. 6b

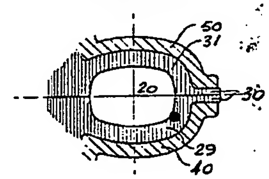


Fig. 6c

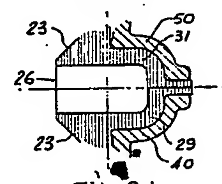


Fig. 6d

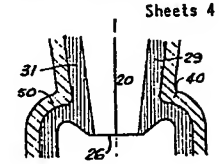


Fig. 5a

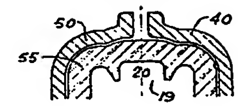


Fig. 5b

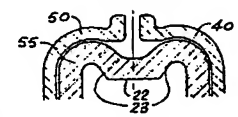


Fig. 5c

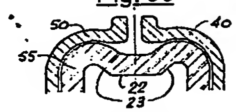


Fig. 5d

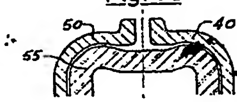


Fig. 5e

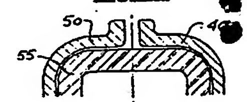


Fig. 5f